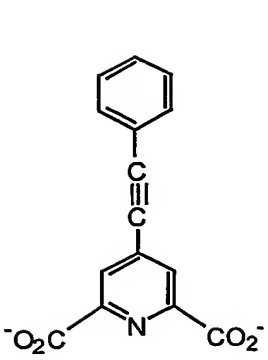
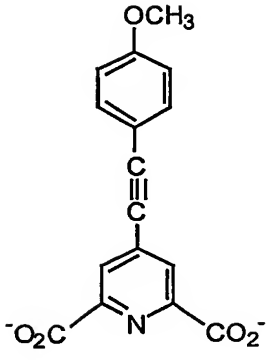


1



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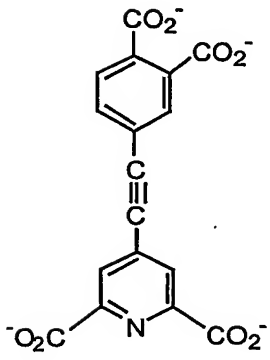

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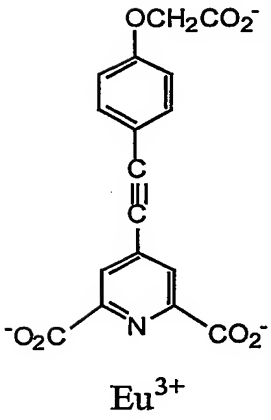

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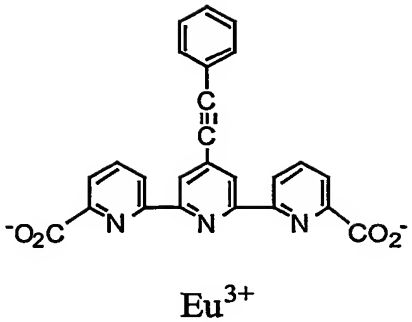

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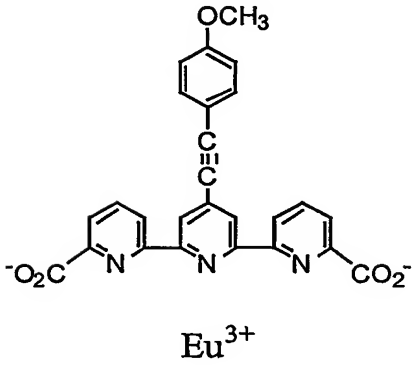
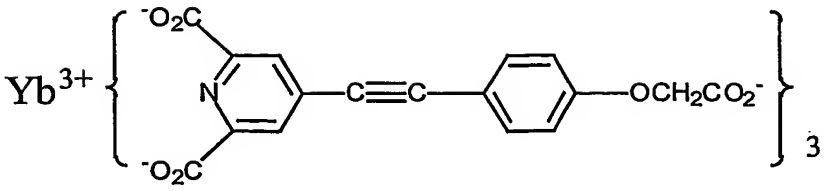
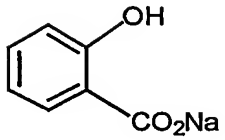


6

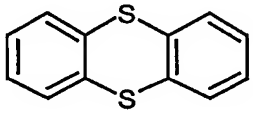
Figure 1



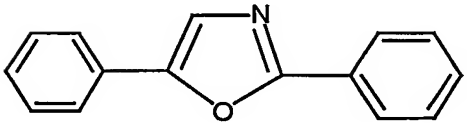
Ytterbium Chelate



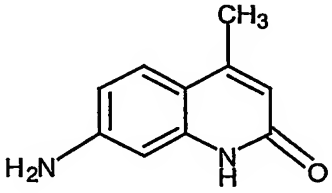
Sodium salicylate



Thianthrene

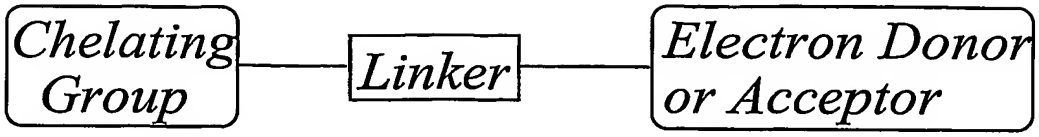


Diphenyloxazole



Carbostyryl 124

Figure 2



Example

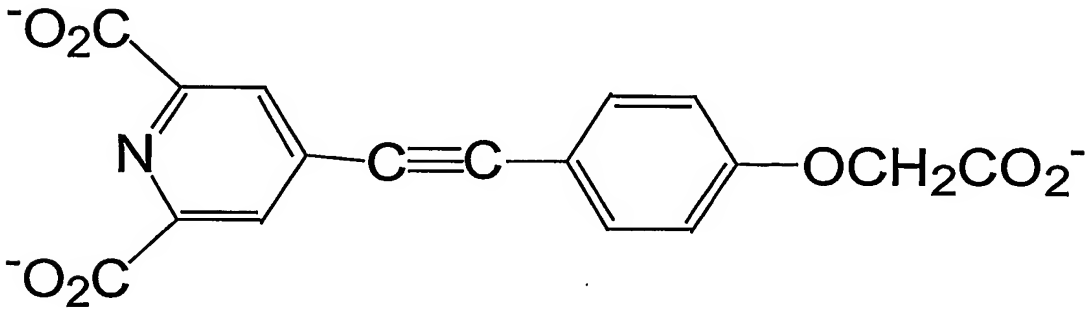


Figure 3

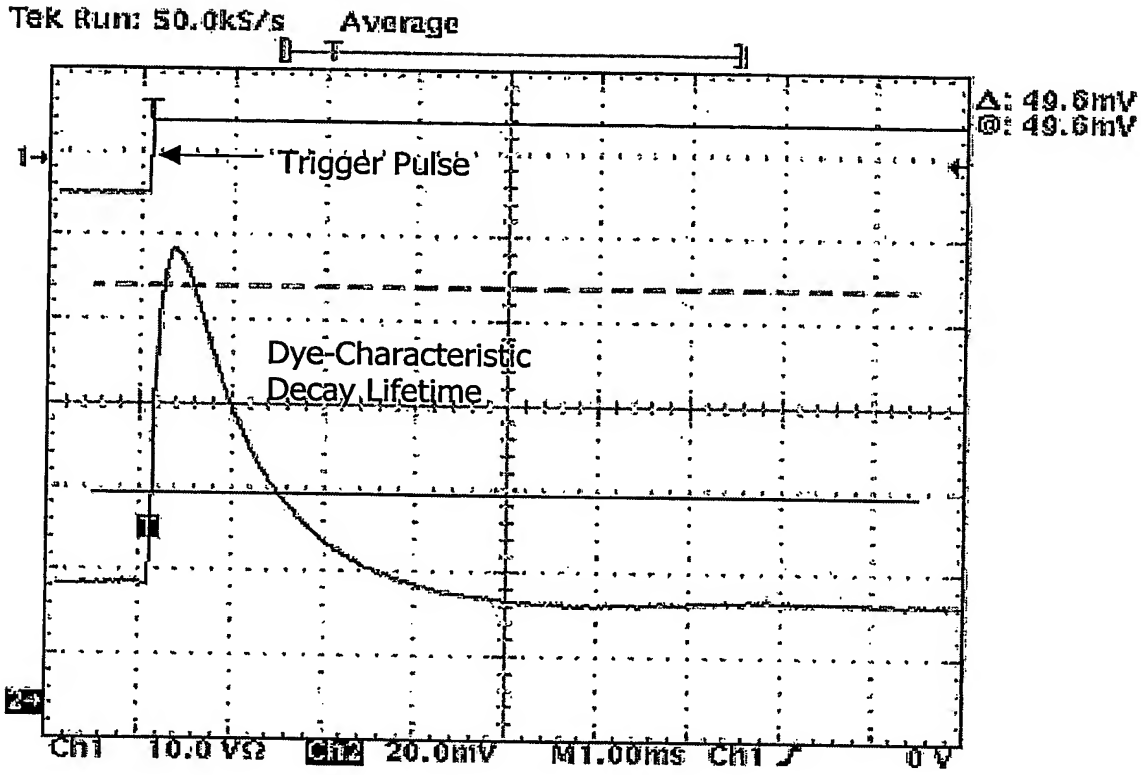

Tek Run: 50.0kS/s Average
Δ: 49.6mV
@: 49.6mV
Trigger Pulse
Dye-Characteristic
Decay Lifetime
Ch1 10.0 V Ω
Ch2 20.0mV
M1.00ms Ch1
0 V

Figure 4

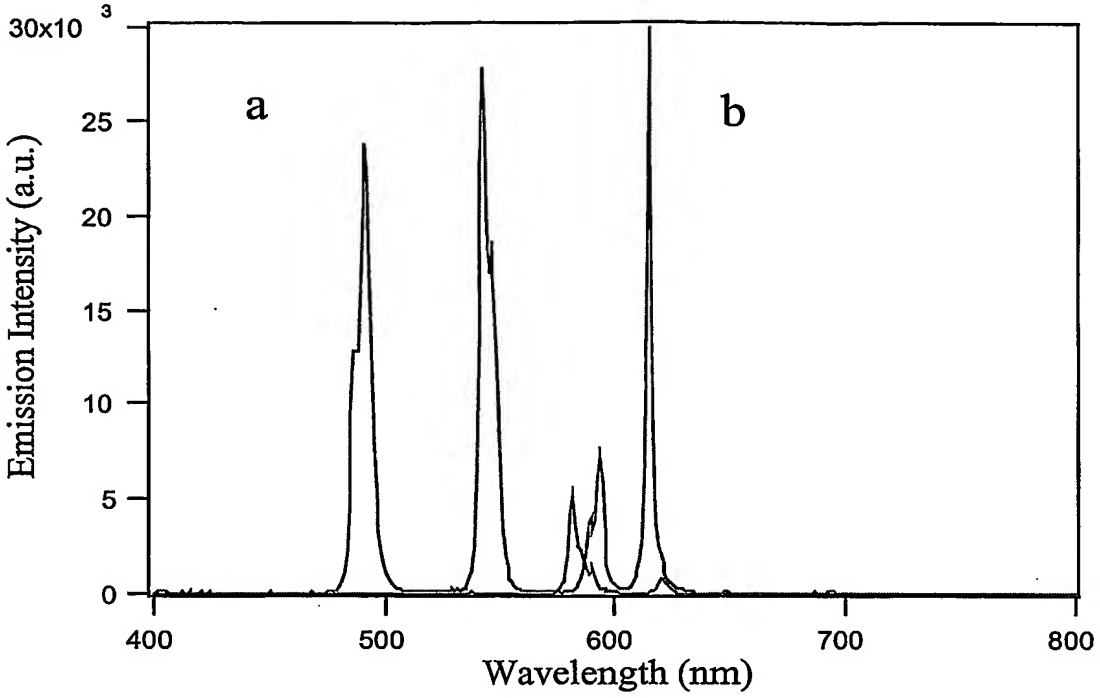

30x10 3
25
20
15
10
5
0
Emission Intensity (a.u.)
a
b
400
500
600
700
800
Wavelength (nm)

Figure 5

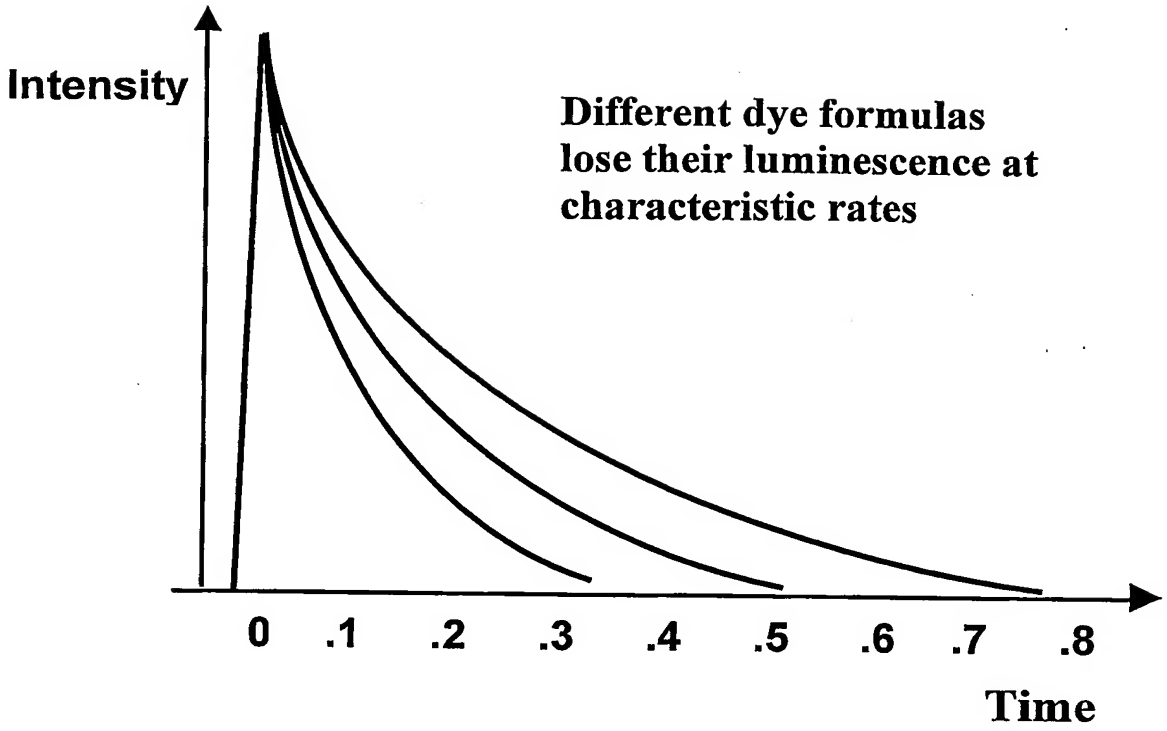

Intensity
Different dye formulas lose their luminescence at characteristic rates
0
.1
.2
.3
.4
.5
.6
.7
.8
Time

Figure 6

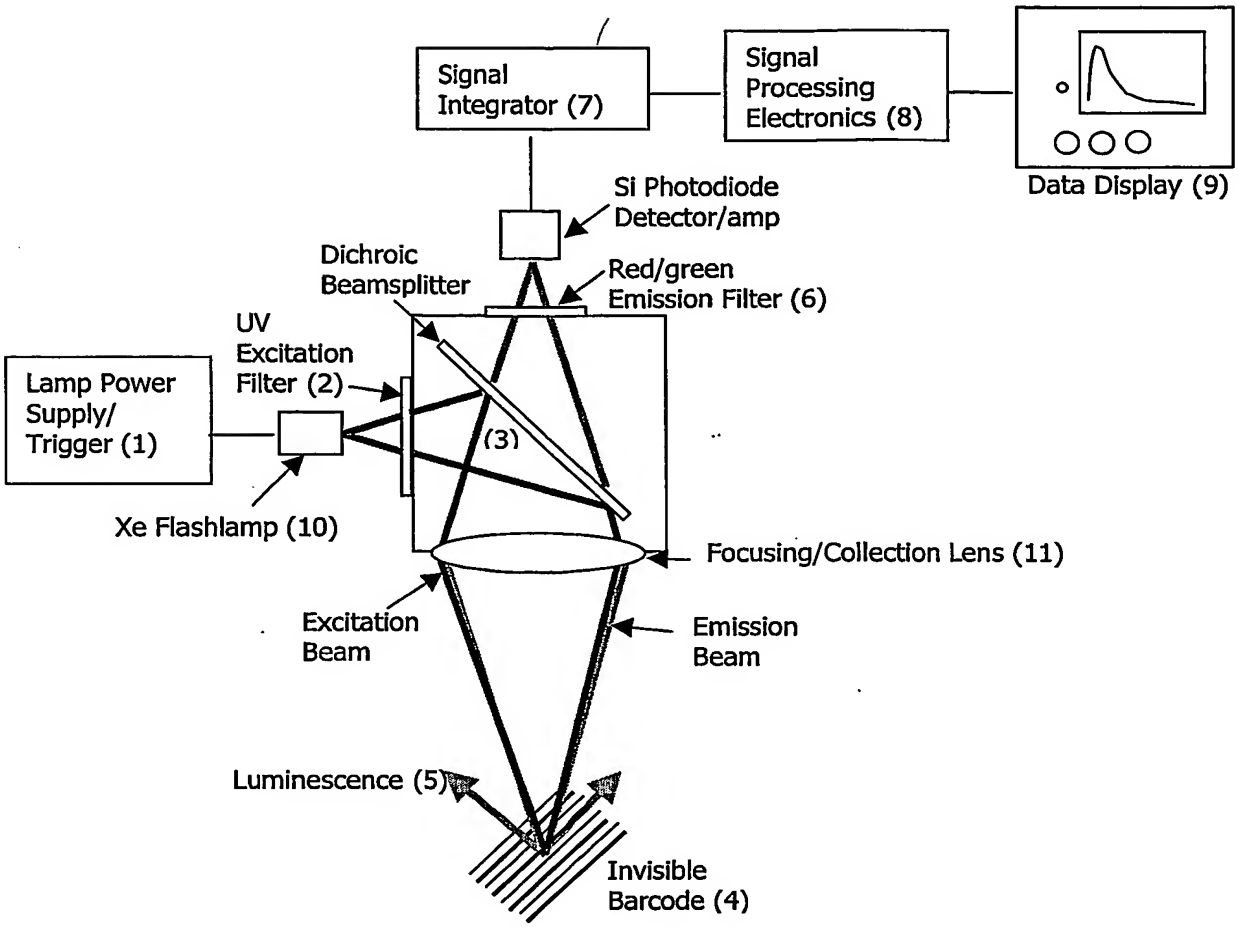
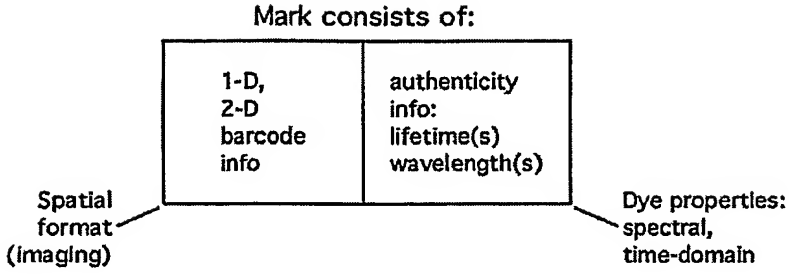

Signal Integrator (7)
Signal Processing Electronics (8)
Data Display (9)
Si Photodiode Detector/amp
Dichroic Beamsplitter
Red/green Emission Filter (6)
UV Excitation Filter (2)
Lamp Power Supply/ Trigger (1)
(3)
Xe Flashlamp (10)
Focusing/Collection Lens (11)
Excitation Beam
Emission Beam
Luminescence (5)
Invisible Barcode (4)

Figure 7


Mark consists of:
1-D, 2-D barcode info
authenticity info: lifetime(s) wavelength(s)
Spatial format (imaging)
Dye properties: spectral, time-domain

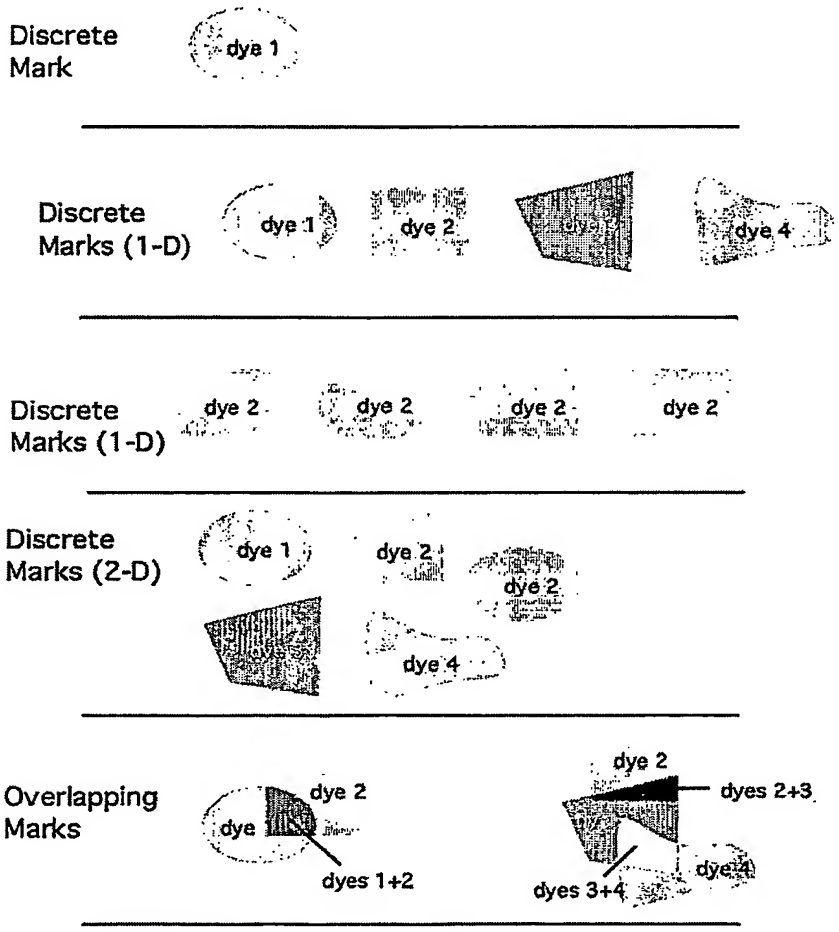

Discrete Mark
dye 1
Discrete Marks (1-D)
dye 1
dye 2
dye 4
Discrete Marks (1-D)
dye 2
dye 2
dye 2
dye 2
Discrete Marks (2-D)
dye 1
dye 2
dye 2
dye 4
Overlapping Marks
dye 2
dye
dyes 1+2
dye 2
dyes 2+3
dye 4
dyes 3+4

Figure 8

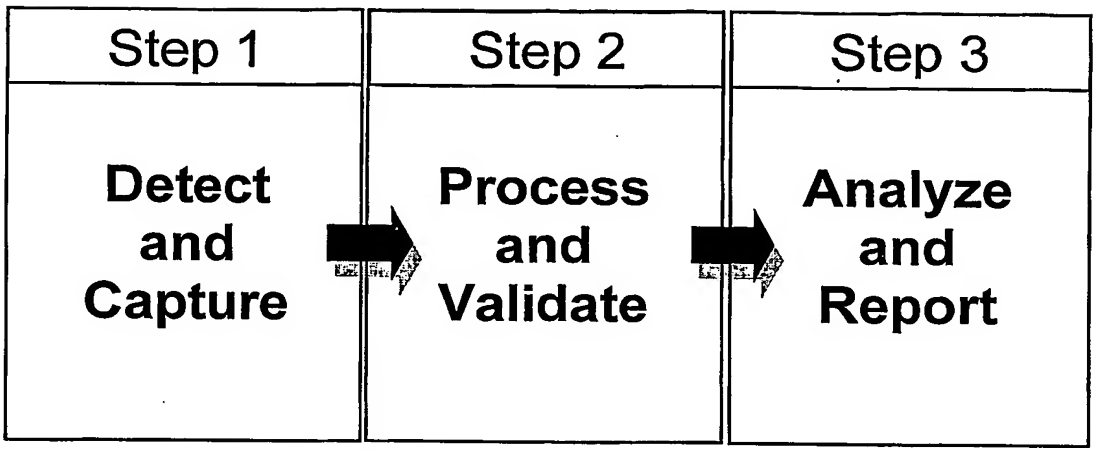


Figure 9A

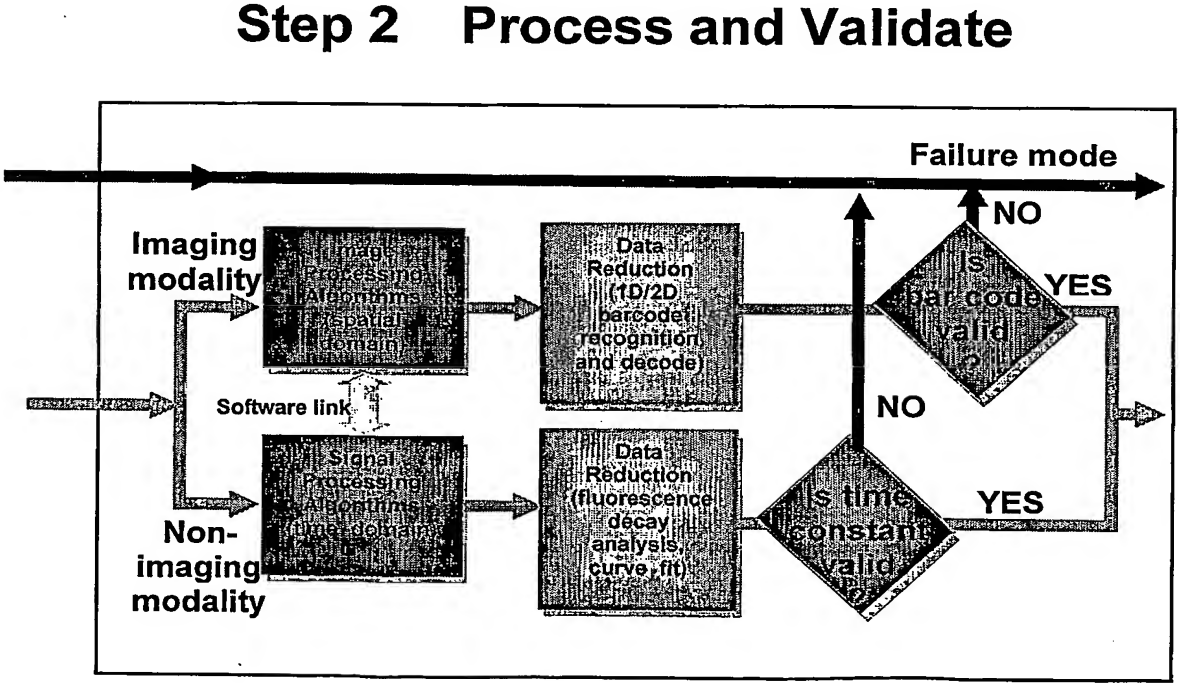


Figure 9B

Step 3 Analyze and Report

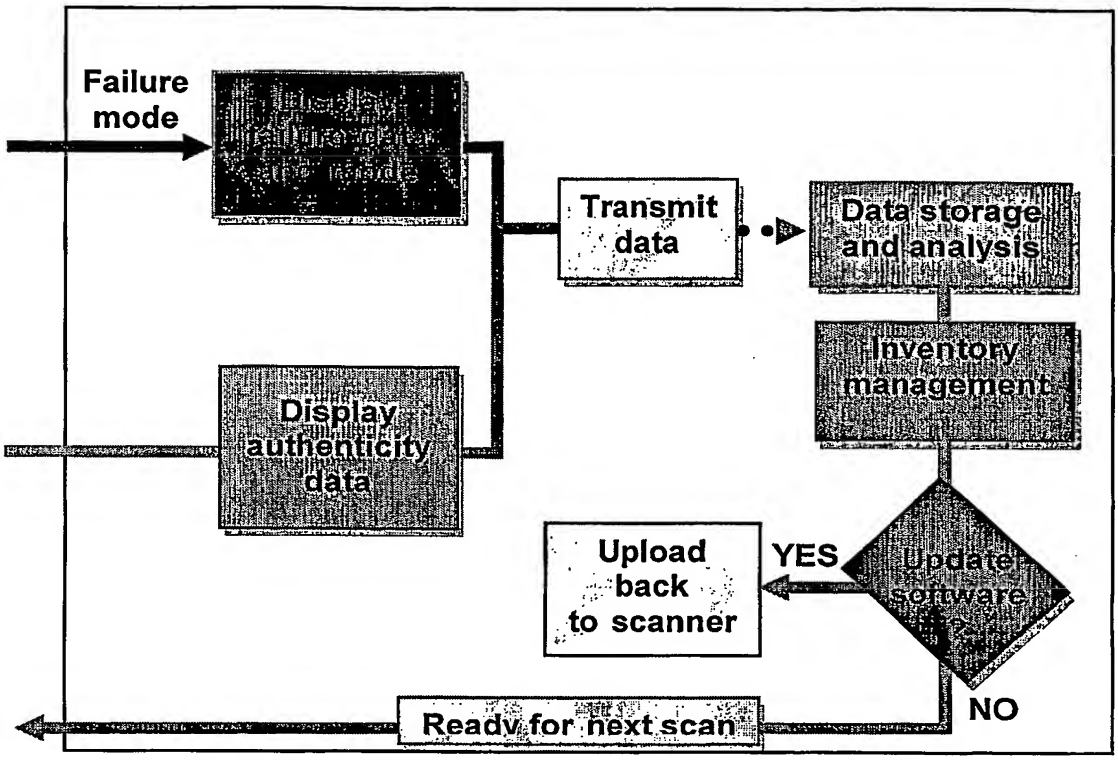


Figure 10

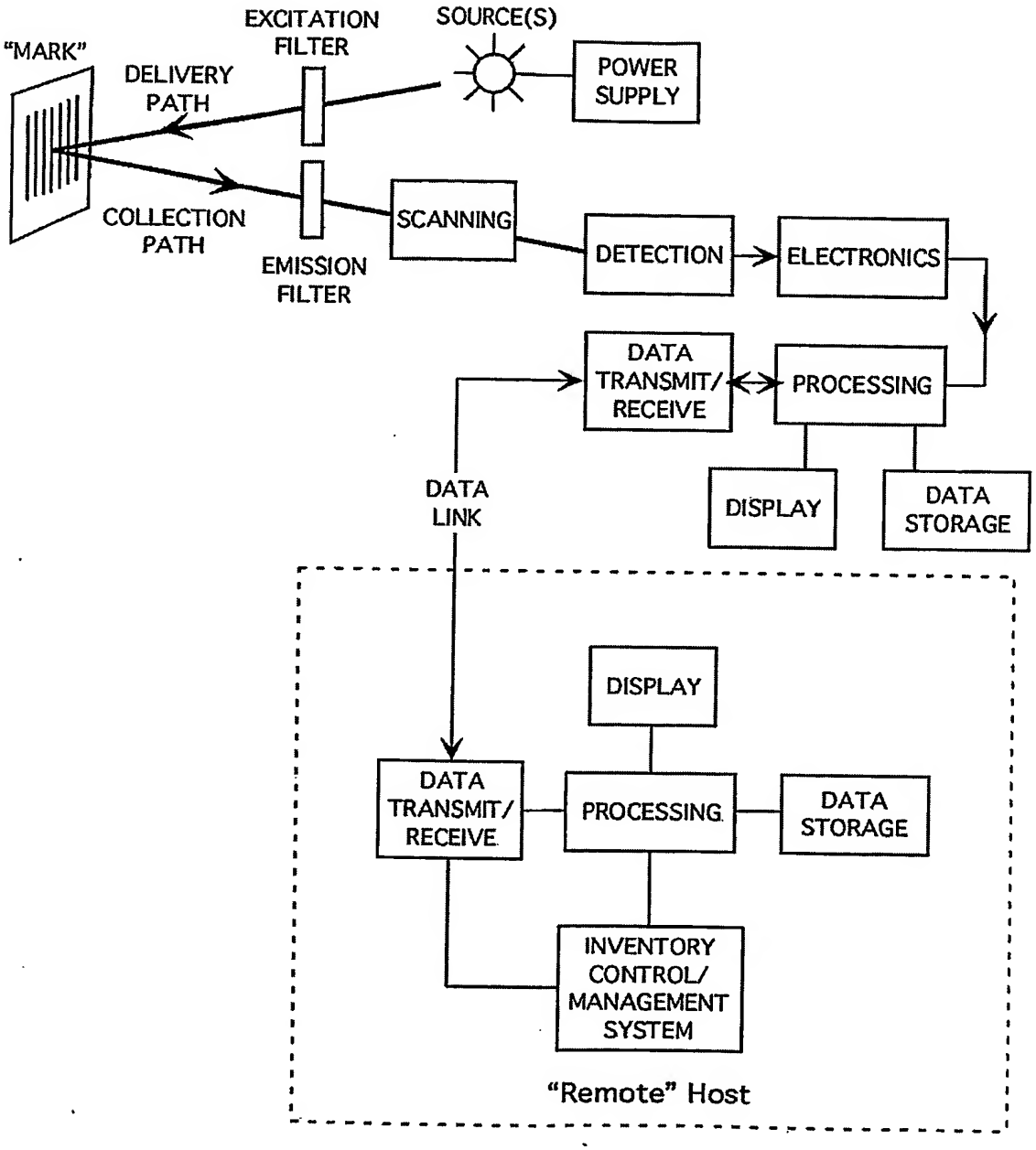

"MARK"
DELIVERY PATH
EXCITATION FILTER
SOURCE(S)
POWER SUPPLY
COLLECTION PATH
EMISSION FILTER
SCANNING
DETECTION
ELECTRONICS
DATA TRANSMIT/ RECEIVE
PROCESSING
DATA LINK
DISPLAY
DATA STORAGE
DISPLAY
DATA TRANSMIT/ RECEIVE
PROCESSING
DATA STORAGE
INVENTORY CONTROL/ MANAGEMENT SYSTEM
"Remote" Host

Figure 11

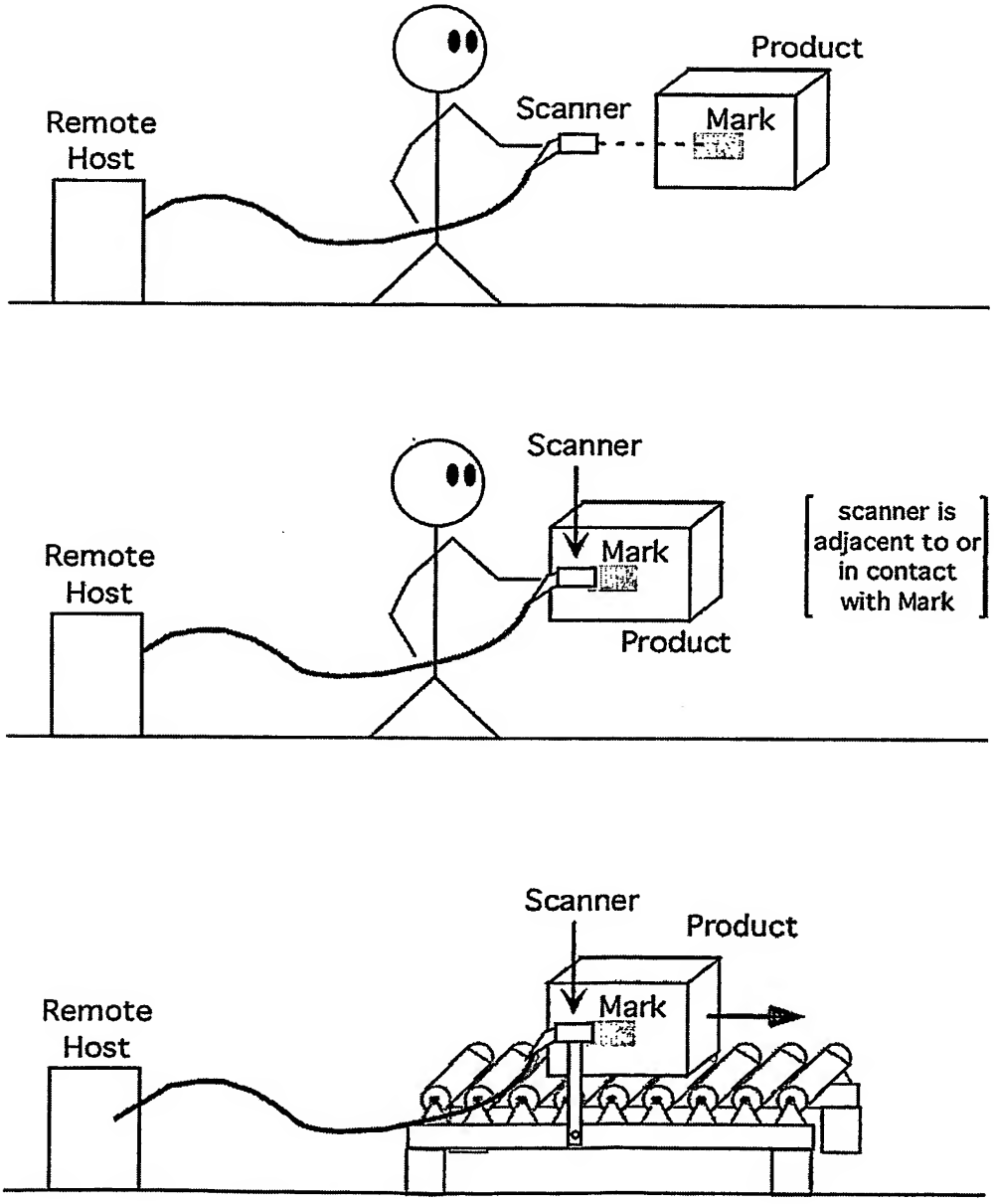

Product
Scanner
Mark
Remote
Host
Scanner
Mark
Remote
Host
Product
scanner is
adjacent to or
in contact
with Mark
Scanner
Product
Mark
Remote
Host

Figure 12

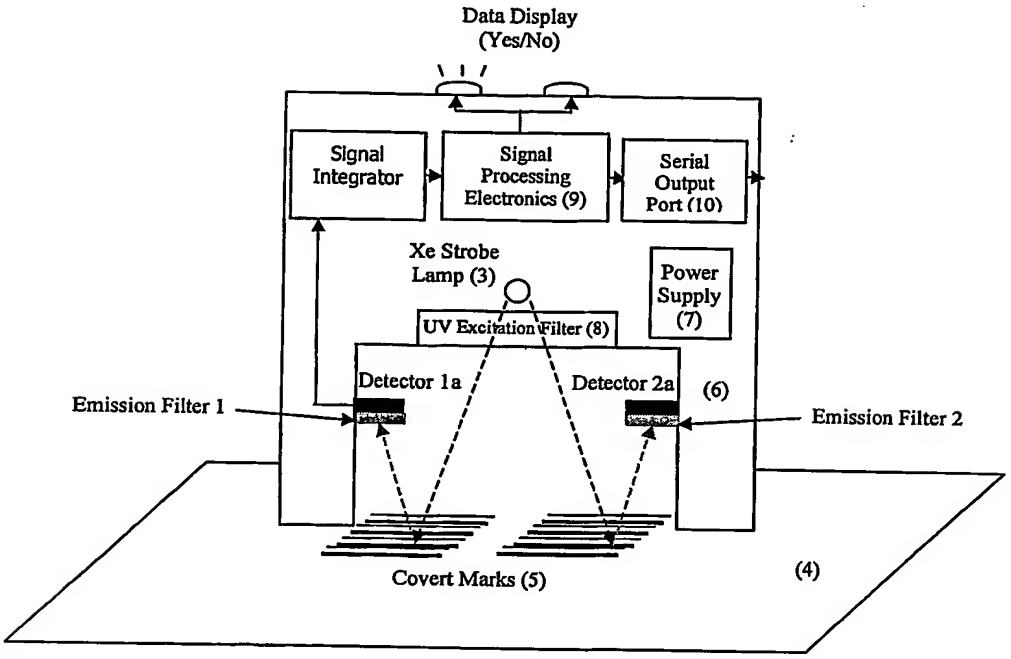

Data Display
(Yes/No)
Signal Integrator
Signal Processing Electronics (9)
Serial Output Port (10)
Xe Strobe Lamp (3)
Power Supply (7)
UV Excitation Filter (8)
Detector 1a
Detector 2a
(6)
Emission Filter 1
Emission Filter 2
Covert Marks (5)
(4)

Figure 13

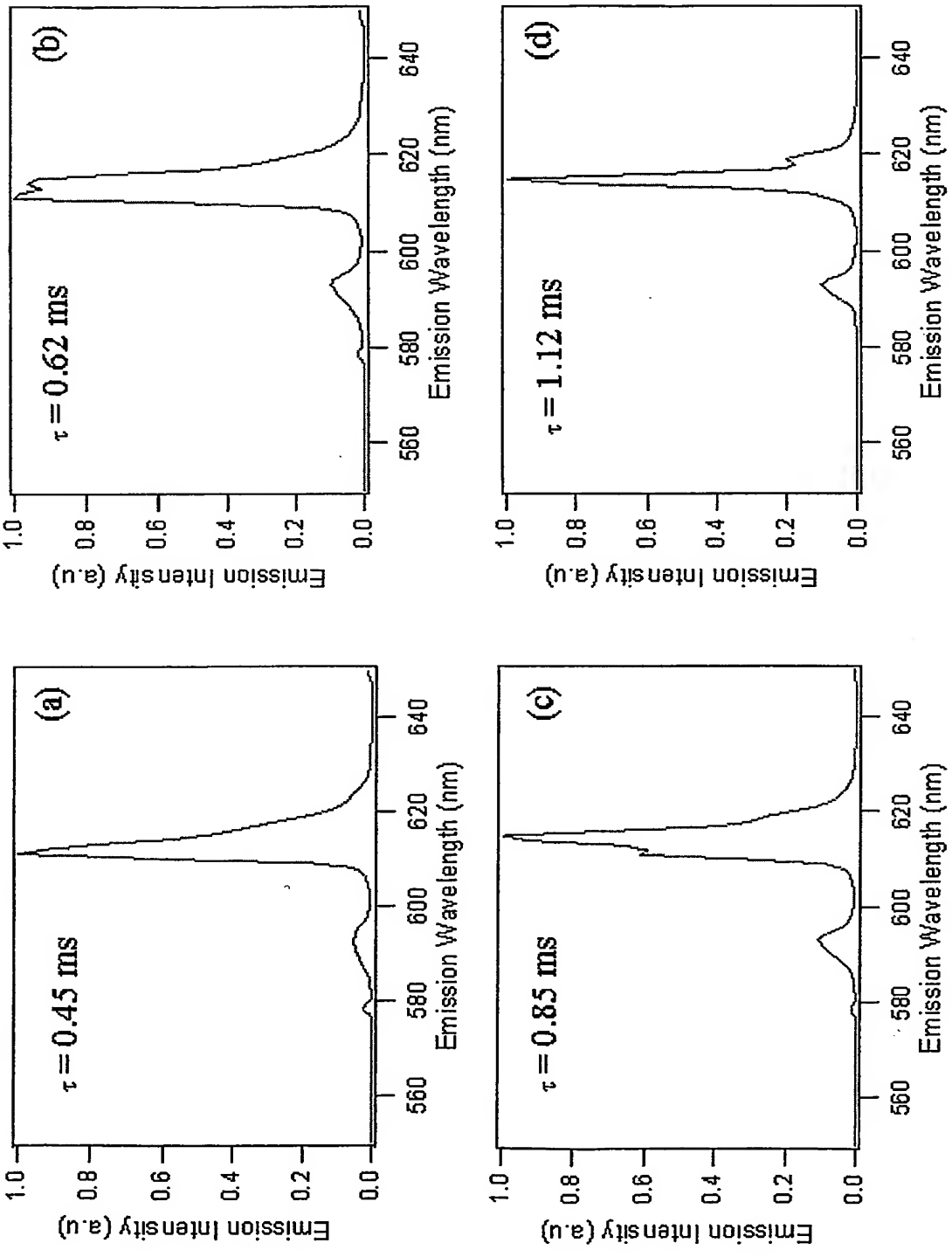

(a)
τ = 0.45 ms
(b)
τ = 0.62 ms
(c)
τ = 0.85 ms
(d)
τ = 1.12 ms
Emission Intensity (a.u)
Emission Wavelength (nm)
0.0
0.2
0.4
0.6
0.8
1.0
560
580
600
620
640

Figure 14

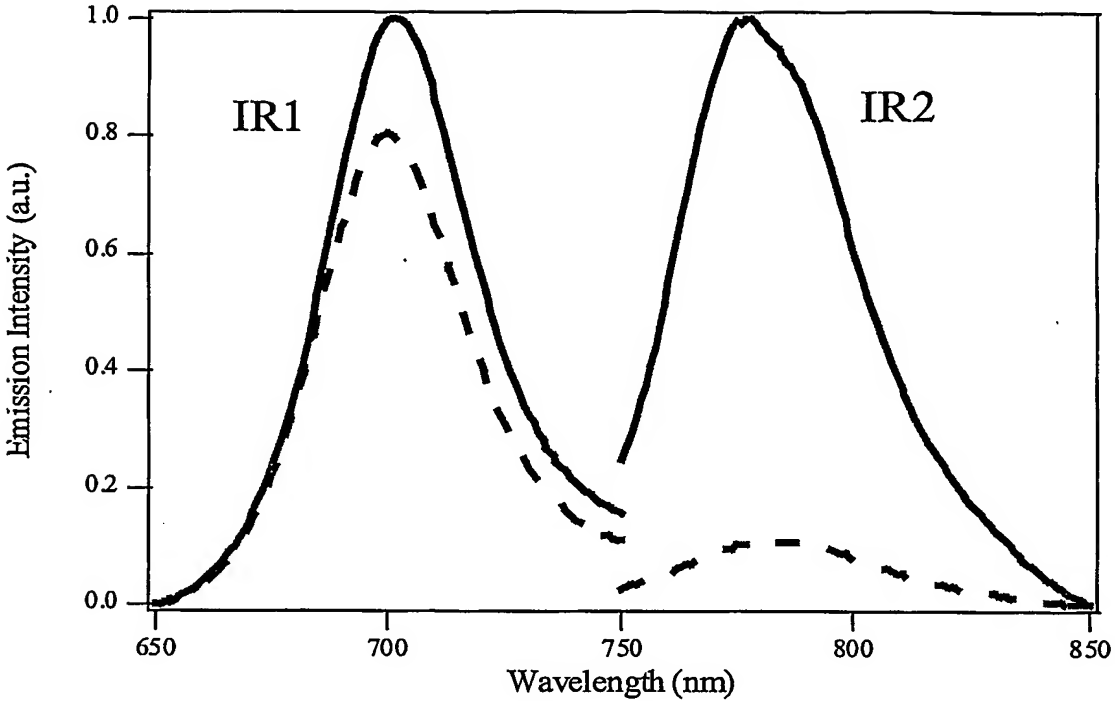

IR1
IR2
Emission Intensity (a.u.)
1.0
0.8
0.6
0.4
0.2
0.0
650
700
750
800
850
Wavelength (nm)

Figure 15

Table 1 Absorption and luminescence parameters for europium chelates [a]

Chelates	$\lambda_{max\ (abs)}$	ε_{max}	$\lambda_{max\ (lum)}$	τ_{lum}
1	*308 nm*	*17400*	*615 nm*	*0.97 ms*
2	*326 nm*	*16600*	*615 nm*	*1.02 ms*
3	*317 nm*	*17200*	*614 nm*	*1.01 ms*
4	*337 nm*	*19300*	*615 nm*	*0.97 ms*
5	*339 nm*	*26000*	*614 nm*	*0.36 ms*
6	*352 nm*	*24200*	*615 nm*	*0.43 ms*

a, Aerated water solutions, pH 8.5; [chelate] = 40 μM; $\lambda_{exc.}$@337 nm for lifetime τ_{lum} measurements; τ_{lum} recorded by monitoring emission at 615 nm.

Table 2 Luminescence lifetime data for chelates

Chelate	Modifiers [a]			
	None	Imidazole	4-MI	IDA
1	*0.97 ms*	*1.19 ms*	*1.22 ms*	*0.45 ms*
2	*1.02 ms*	*1.21 ms*	*1.37 ms*	*0.48 ms*
3	*1.01 ms*	*1.23 ms*	*1.19 ms*	*0.46 ms*
4	*0.97 ms*	*1.27 ms*	*2.03 ms*	*0.60 ms*
5	*0.36 ms*	*0.65 ms*	*0.54 ms*	*0.50 ms*

a, Modifiers at 1.0 mM concentration; Imidazole, 4-methylimidazole (4-MI), and iminodiacetic acid (IDA), were added to an application medium of 200 μM chelate in water (pH9.0) and applied to plain paper; lifetimes (units of ms) from exponential luminescence decay curves ($\lambda_{exc} = 337$ nm; $\lambda_{lum} = 615$).